Chapter 3. Convective Dynamics

Photographs © Todd Lindley

This is a major chapter in our MM course

Textbook materials for reading:

Holton p.287 – 303
Houze 268 – 295
Bluestein Vol II p 445-462
(more later when we get into squall lines and supercells)

3.1. Introduction

Issues with convection:

- types of storms
- necessary conditions for
- large-scale organization
- feedback to environment
- dynamics of
- factors that control movement and rotation
- prediction of

First let's look at the general modes of convection. We will later focus more specifically on deep convective storms.

Thunderstorms

Definition: A thunderstorm is a local storm, invariably produced by a cumulonimbus cloud, that always is accompanied by lightning and thunder. It usually contains strong gusts of wind, heavy rain, and sometimes hail. We often use the word "convection" to describe such storms in a general manner, though the term convection specifically refers to the motion of a fluid resulting in the transport and mixing of properties of the fluid. To be more precise, a convective cloud is one which owes its vertical development, and possibly its origin, to convection (upward air currents).

Storm Classification

Although a continuous spectrum of storms exists, meteorologists find it convenient to classify storms into specific categories according to their structure, intensity, environments in which they form, and weather produced.

The most basic classification includes

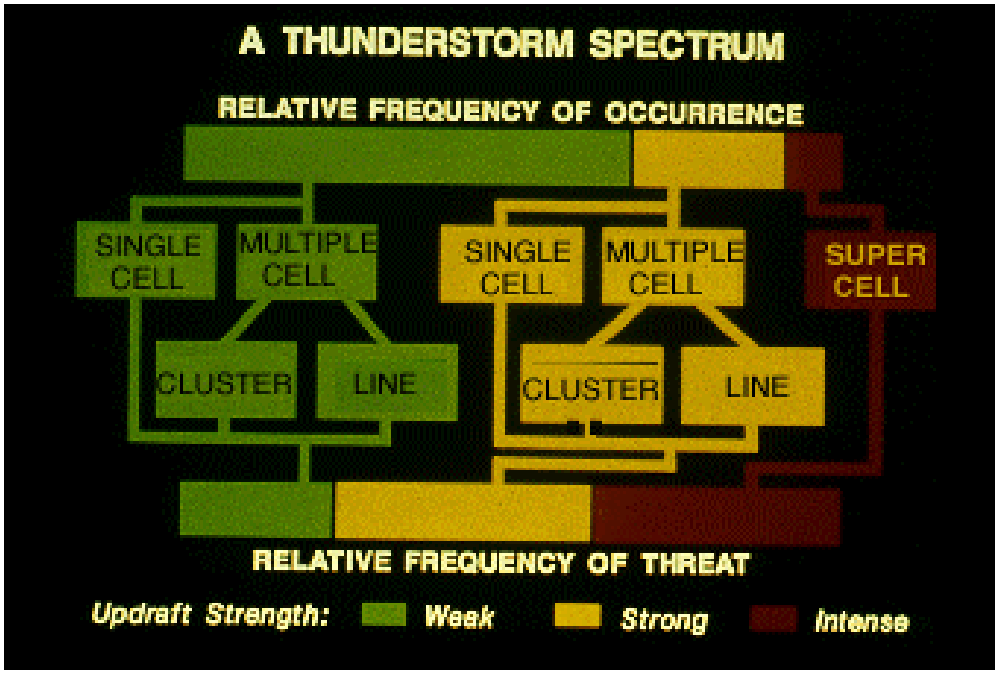
- Single-cell or air-mass storm
  Typically last 20-30 minutes. Pulse storms can produce severe weather elements such as downbursts, hail, some heavy rainfall and occasionally weak tornadoes.

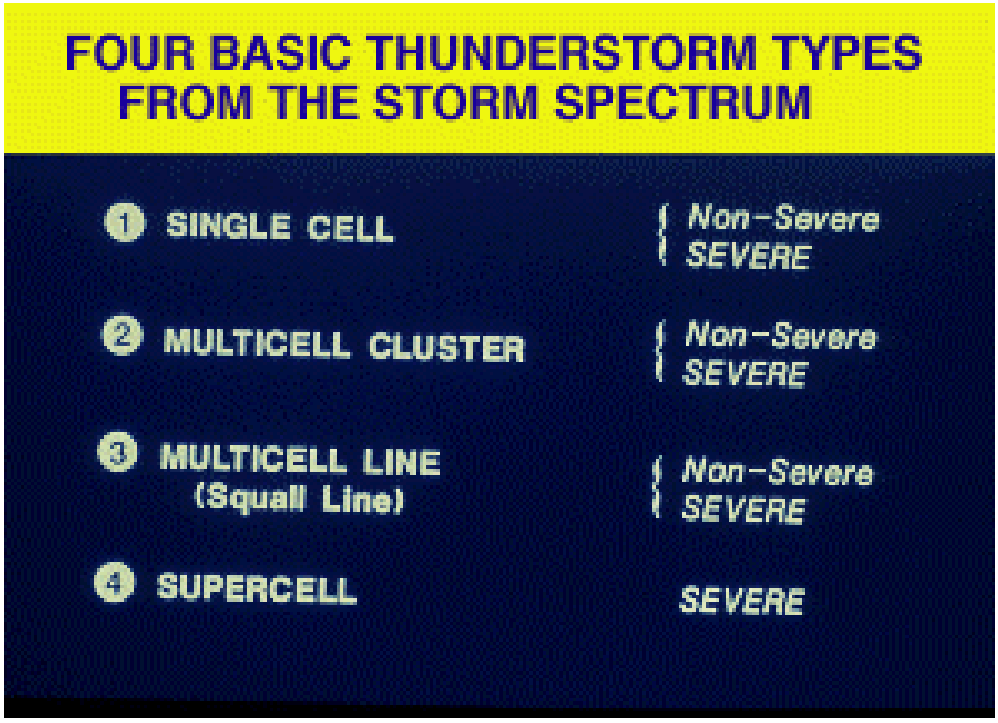
- Multicell cluster storm
  A group of cells moving as a single unit, with each cell in a different stage of the thunderstorm life cycle. Multicell storms can produce moderate size hail, flash floods and weak tornadoes.

- Multicell Line (squall line) Storms
  Multicell line storms consist of a line of storms with a continuous, well developed gust front at the leading edge of the line. Also known as squall lines, these storms can produce small to moderate size hail, occasional flash floods and weak tornadoes.

- Supercells

  Defined as a thunderstorm with a rotating updraft, these storms can produce strong downbursts, large hail, occasional flash floods and weak to violent tornadoes.





Web Resources
Single-Cell (Airmass) Thunderstorms
(http://ww2010.atmos.uiuc.edu/(Gh)/guides/mtr/svr/type/sngl/ovr.rxml)

Thunderstorms (http://snrs.unl.edu/amet498/versaw/)

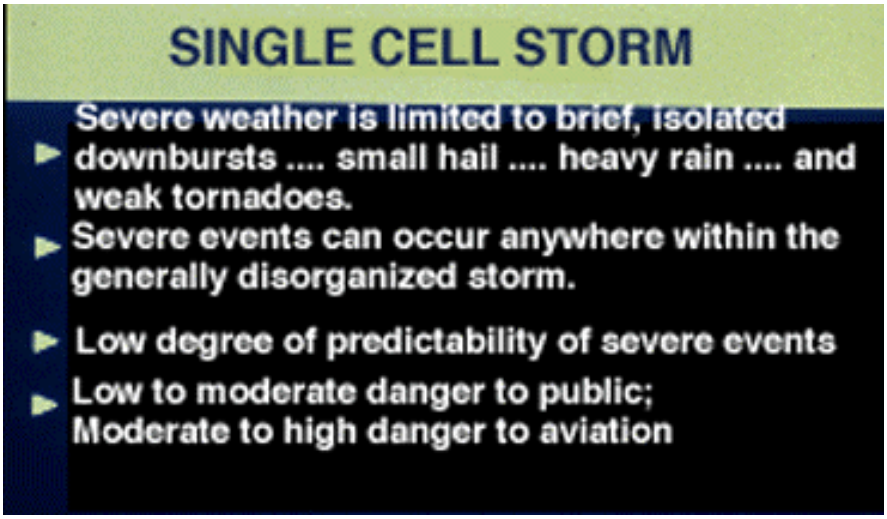
3.2 Ordinary or "airmass" storm

3.2.1. Main Characteristics

- Consists of a single cell (updraft/downdraft pair)
- Forms in environment characterized by large conditional instability and weak vertical shear
- Vertically erect → built-in self-destruction mechanism
- Can produce strong straight-line winds or microburst
- Life cycle is generally < 1 hour, usually 3-45 min
- These storms form in weakly-forced environments, and are driven primary by convective instability rather than the ambient winds
- They are some times called "air-mass" storm because they form within air-masses with relative horizontal homogeneity

From http://ww2010.atmos.uiuc.edu:

Single cell storms typically do not produce severe weather and usually last for 20-30 minutes. Also known as pulse storms, single cell storms seem quite random (perhaps because of our lack of understanding) in the production of brief severe events such as downbursts, hail, some heavy rainfall, and occasional weak tornadoes.



The "degree of predictability" is extremely low as forecasters are never quite sure which storm will produce severe weather and from which portion of that storm the severe events will occur. However, the microburst threat to aviation cannot be over-emphasized.

Photograph by: NSSL

This is a single cell storm, looking east from about 15 miles. The storm was moving east (into the photo). Some of the anvil cloud has been left behind the storm, but the greater portion of the anvil is blowing off in advance of the storm and is not observable from this perspective. (May storm in the Texas Panhandle near Amarillo.)

Photograph by: Moller

True single cell storms are relatively rare since even the weakest of storms usually occur as multicell updraft events. Some single cell thunderstorms are called "air mass" storms. This late May storm in Oklahoma, looking northeast from about 20 miles, occurred with weak to moderate vertical wind shear. It did not produce any severe weather.

3.2.2. Basic Dynamics

$$\frac{dw}{dt} = -\frac{1}{\bar{r}}\frac{\partial p'}{\partial z} + g\left(\frac{q'}{\bar{q}} + 0.61q_v' - L\right)$$

vertical acceleration	PGF	thermal buoyancy	vapor buoyancy	liquid water loading

where L = liquid+ice wanter content. Note that the water vapor contributes to the buoyancy of air parcel. The combined effect can be also be expressed in terms of virtual potential temperature.

Stages of storm formation:

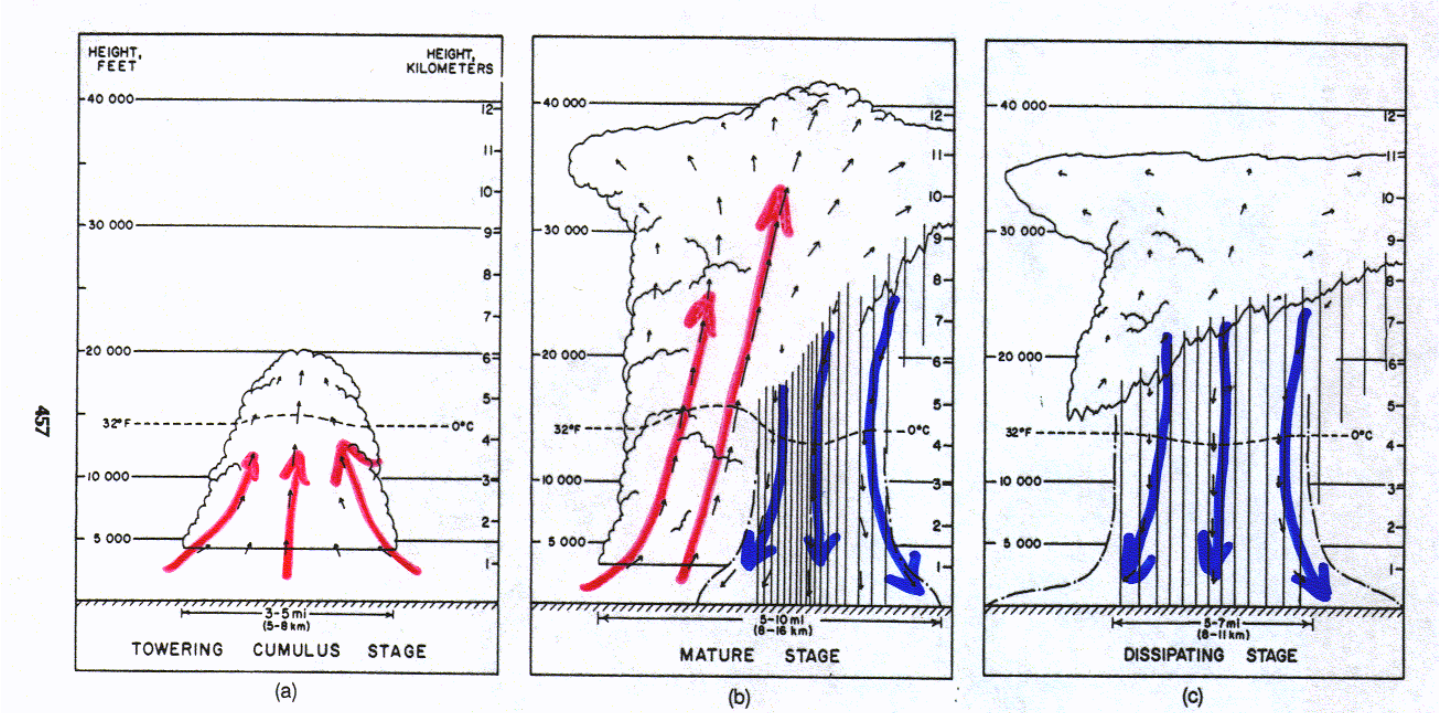


Figure 3.15 The Byers–Braham model of the three stages in the life of a thunderstorm: (a) towering cumulus stage, (b) mature stage, and (c) dissipating stage. Arrows indicate the sense of air motion (from Doswell, 1985).

- Towering cumulus stage
- Mature stage
- Dissipating Stage